MAY 1977

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

Executive Summary
Improved Planning and Production Control
Volume I

U.S. DEPARTMENT OF COMMERCE
MARITIME ADMINISTRATION

IN COOPERATION WITH
BATH IRON WORKS CORPORATION

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1. RESEARCH GOAL – REDUCING COST OF SHIP CONSTRUCTION

The goal of the Planning and Production Control Research Task, like all other tasks under the National Shipbuilding Research Program, is to reduce the cost of building ships in U.S. Shipyards. But unlike other projects which are mainly concerned with improving physical production processes like welding, materials handling, and surface coating where results are readily observable, Planning and Production Control is directed toward the less tangible factors of time, schedules, standards and budgets where results are equally significant though not directly visible.

Managers recognize that the cost of constructing a ship varies as a function of the scheduled construction time. If the construction schedule is highly compressed, costs will tend to be higher due to premium shift labor, crowded work stations, increased expediting, excessive rework to accommodate inevitable engineering changes, and other well known inefficiencies which compressed schedules always entail. If, on the other hand, schedules are unduly protracted, construction costs will also be higher due to extended facility occupancy times, low labor and resource utilization, and carrying charges for high inventory and work-in-process. Between these extremes, there is an optimum schedule where construction costs are at a minimum. (Figure 1).

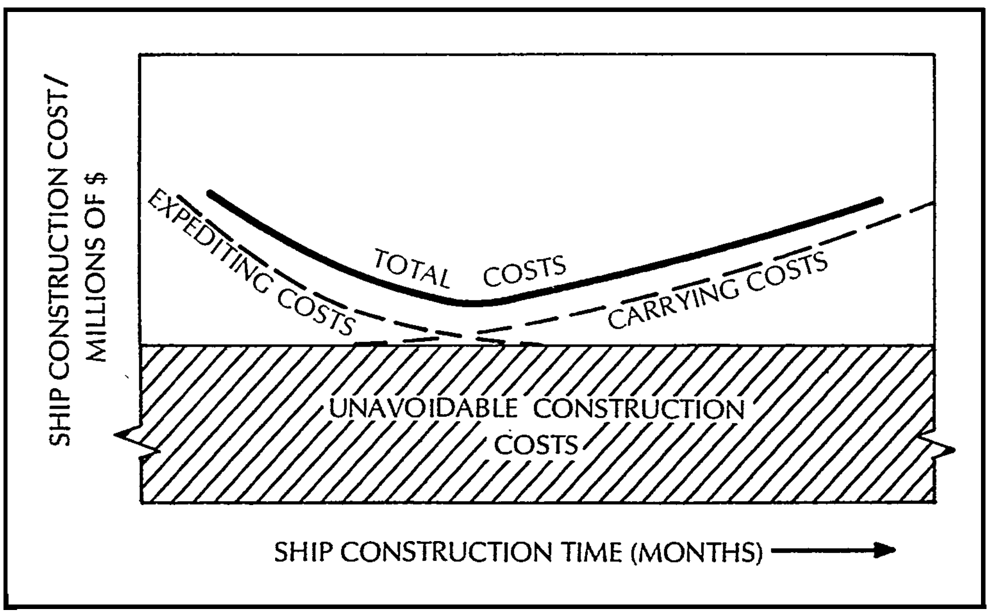


FIGURE 1: IMPACT OF SCHEDULED SHIP CONSTRUCTION TIME ON CONSTRUCTION COST

A striking parallel exists with construction labor budgets. If budgets are underestimated, then labor force manning levels will be inadequate to maintain schedules, and either delivery dates will slip, resulting in contract penalty costs, or labor must be diverted from other projects, causing delays and disruptions throughout the shipyard. If labor budgets are overestimated, it is a well known fact that labor costs will grow inevitably to match the budget.

For both budgets and schedules, then, there are optimum points at which construction costs are minimized. A specific objective of the Planning and Production Control research was to find practical methods by which shipyard managers can approximate these optimum schedules and budgets. In this sense, the project followed the guiding spirit of the National Shipbuilding Research Program "combining the factors of production in a new way to improve profits or reduce cost". *

2. RESEARCH PLAN – WHAT HAD TO BE DONE

The plan (Figure 2) for guiding Planning and Production Control research followed the same general pattern successfully used for many other projects under the National Shipbuilding Research Program.

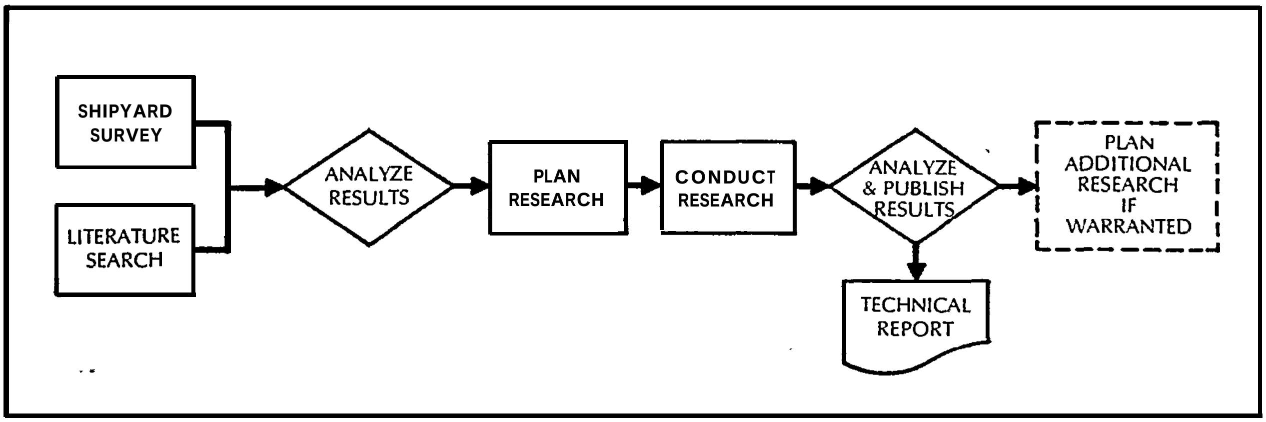


FIGURE 2: RESEARCH PLAN

The first step was to survey planning and production control methods being used in U.S. and selected foreign shipyards. This step established the baseline of current practice against which results of the research could be evaluated. Concurrently, a literature search was conducted to identify planning and production control techniques used in related and allied industries which might prove beneficial to the shipyards.

An experiment was then conducted in a representative portion of the ship construction process to gather data which would lead to conclusions for cost reduction possibilities through the use of improved planning and production control methods.

3. RESEARCH – WHAT WAS DISCOVERED

Shipyard Survey

The shipyard survey showed that most shipyards use rather simplistic, historically derived budgeting and scheduling rules expressed typically in man-hours-per-ton or tons-per-week. While these rules are easy to apply, they do not take into account variations in work complexity or type of material - facts which in turn suggested that improvement might be possible by finer tuning of times and budgets to actual work content. Whenever the need for greater accuracy arises, then, adjustments can be made by skilled and experienced planners to bring budgets and schedules more in line with reality.

* J. J. Garvey, The National Shipbuilding Research Program 1971-1976, Presentation to the Philadelphia Section, Society of Naval Architects and Marine Engineers, April 9, 1976.

Literature Survey

The literature research showed, in particular, that an increasing number of industrial firms had switched from simple, intuitive planning and budgeting rules to more complex rules - Engineered Standards - derived from physical measurement of selected production processes. In converting to Engineered Standards, these firms, almost without exception, experienced at least a 10% improvement in productivity at the process level (e.g., welding), and an additional 10% improvement in overall productivity through more effective scheduling and machine/plant loading which the precise, Engineered Standards permitted.

Survey Conclusions

The findings of these two surveys clearly indicated that one of the most promising avenues of exploration would be the use of Engineered Standards in shipyard planning and production control. Accordingly, subsequent research was focused on the evaluation of Engineered Standards in the construction of a typical commercial ship.

The pilot setting selected was a steel fabrication shop - a kind of half-way house between industrial plants where Engineered Standards have been successfully used for many years, and the panel, assembly, and outfit shops, and erection areas where the functions performed are unique to shipbuilding.

Engineered Standards

In the more progressive industrial firms Engineered Standards are used to all levels in the production management hierarchy (Figure 3).

At the bottom level, Process Standards* specify the rates at which certain elementary operations (e.g., layout, burning, fitting, welding) should be accomplished under specified conditions (e.g., welding currents) on various materials (e.g., plates of different thickness). Process Standards are developed by adjusting the variables of the process and measuring results' until optimum output levels are produced. These optimum outputs then become the established Process Standards for use by first level supervision.

The next level is the Production Standard which is a composite of all Process Standards required to accomplish a specific job.* The Production Standard is the basic vehicle for control of work within a shop.

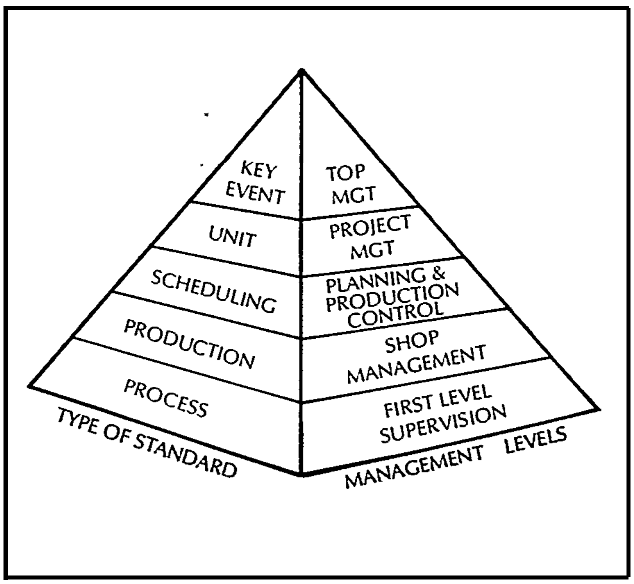


FIGURE 3. THE PYRAMID OF STANDARDS

" The Technical Note at !he end of this report contains sampl, process Standards and illustrates their use in preparing production Standards.

The next step up in the hierarchy is the Scheduling Standard. Since there are literally tens-of-thousands of discrete jobs in the construction of a ship, it would be practically impossible and financially prohibitive to develop the overall schedule and budget for a ship from the many individual Production Standards. Accordingly, several Production Standards may be merged to represent larger packages of work - thus creating Scheduling Standards which are more readily usable while still providing acceptable accuracy. These become the Scheduling Standards used for central planning and scheduling of ship construction projects.

Standards at higher levels in the pyramid are developed in analogous fashion, keyed to the needs of the higher management levels.

Scheduling Standards vs Traditional Rules

Traditional planning rules are applied at the same level (level three in Figure 3) as Scheduling Standards, and serve the same purpose. The difference between the two lies solely in the respective methods of development. Traditional rules are derived from historical experience of performance on prior projects - usually specified in man-hours-per-ton or tons-per-week. Scheduling Standards are developed from engineering measurements of the actual operations involved.

Steel Fabrication Shop Experiment

The objective of the experimental research conducted, in terms of Engineered Standards, was:

> To evaluate the cost reduction potential offered by the use of engineered Scheduling Standards in those shipyards which use traditional planning and scheduling rules.

The two key indices that management uses to measure shipyard, shop, and work center performance are schedule compliance and productivity. Accordingly, these were the two parameters measured in the evaluation of Engineered Standards. Process Standards for layout, burning, fitting and welding were developed for the steel fabrication shop along with higher level Production Standards for larger jobs and Scheduling Standards for work packages covering steel fabrication operations for complete erection units.

The project on which the Engineered Standards were applied during the experiment was a contract for four 20,000 DWT commercial cargo ships. At the time the experiment was started, all steel fabrication work on the first two ships in the series had been completed. Schedule compliance and productivity indices were available for these two ships to provide the baseline for later comparison with experimental results. Engineered Standards were applied at the mid-way point in the fabrication of parts for the third ship, and carried over into fabrication operations for the fourth ship.

Experimental Results

Improvement in schedule compliance (Figure 4) following the introduction of Scheduling Standards was dramatic.

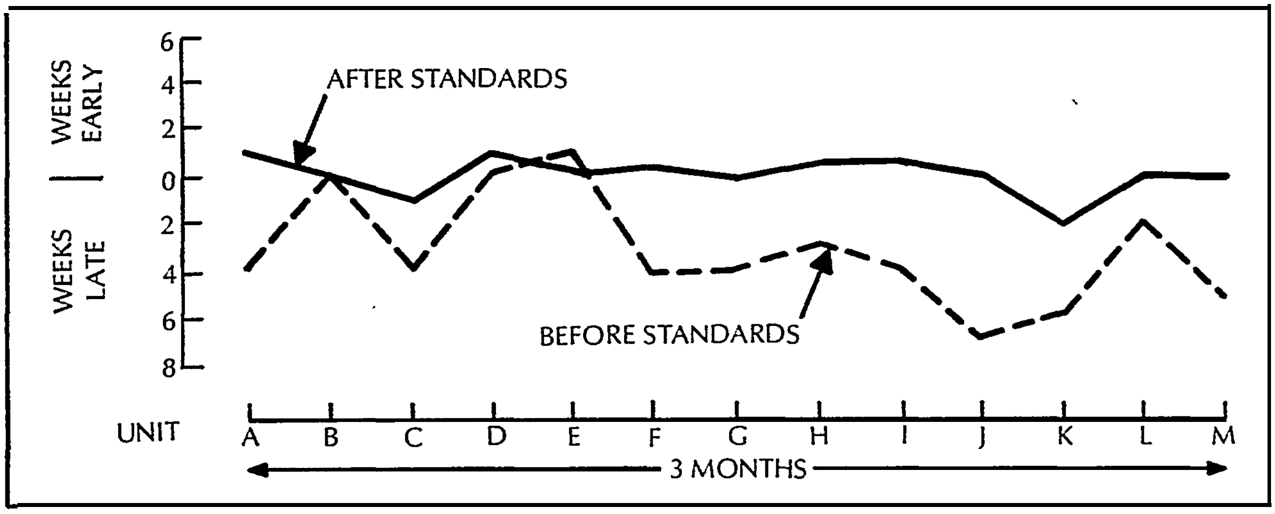


FIGURE 4: IMPACT OF ENGINEERED STANDARDS
ON SCHEDULE COMPLIANCE

Before Engineered Standards were used for steel fabrication shop scheduling and loading, the completion of units averaged 3.2 weeks late. For the three month period in which Engineered Standards were used for shop scheduling, average time late was reduced to zero weeks.

Even more impressive were improvements in productivity. Here application of Engineered Standards resulted in a projected reduction of 21% in man-hours-per-ton (Figure 5) beyond normal learning effects.

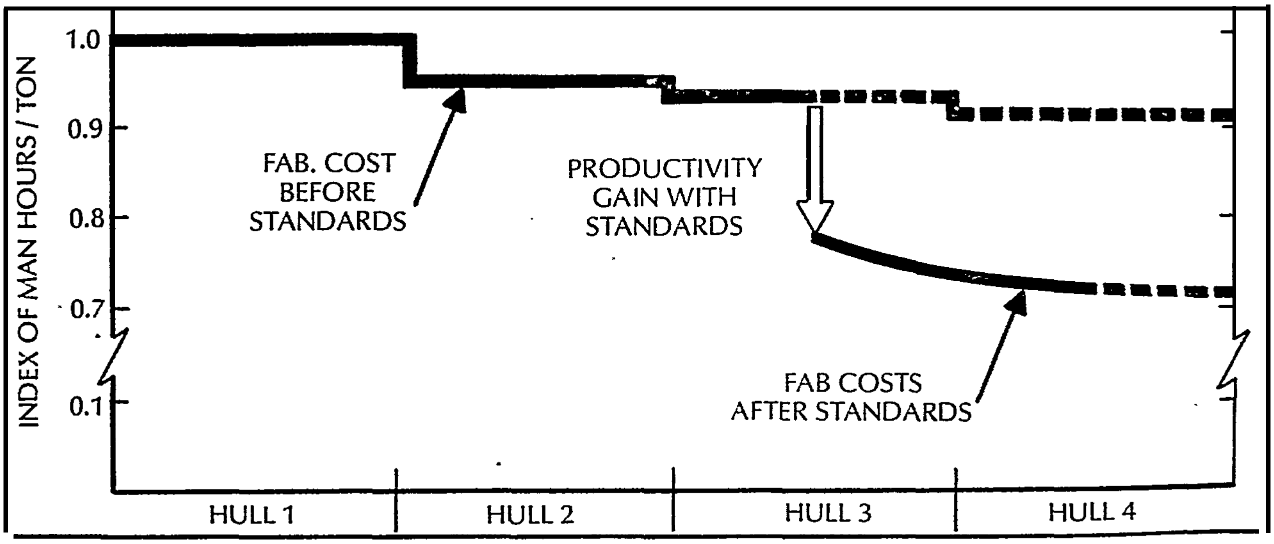


FIGURE 5: PROJECTED PRODUCTIVITY IMPACT
OF ENGINEERED STANDARDS

The impact of greatest significance was the reduction in the cost (Figure 6) of steel fabrication operations for each of the four ships. The cost of developing and applying standards was included in the projected fabrication costs for hulls 3 and 4, so the projected savings represented are net savings.

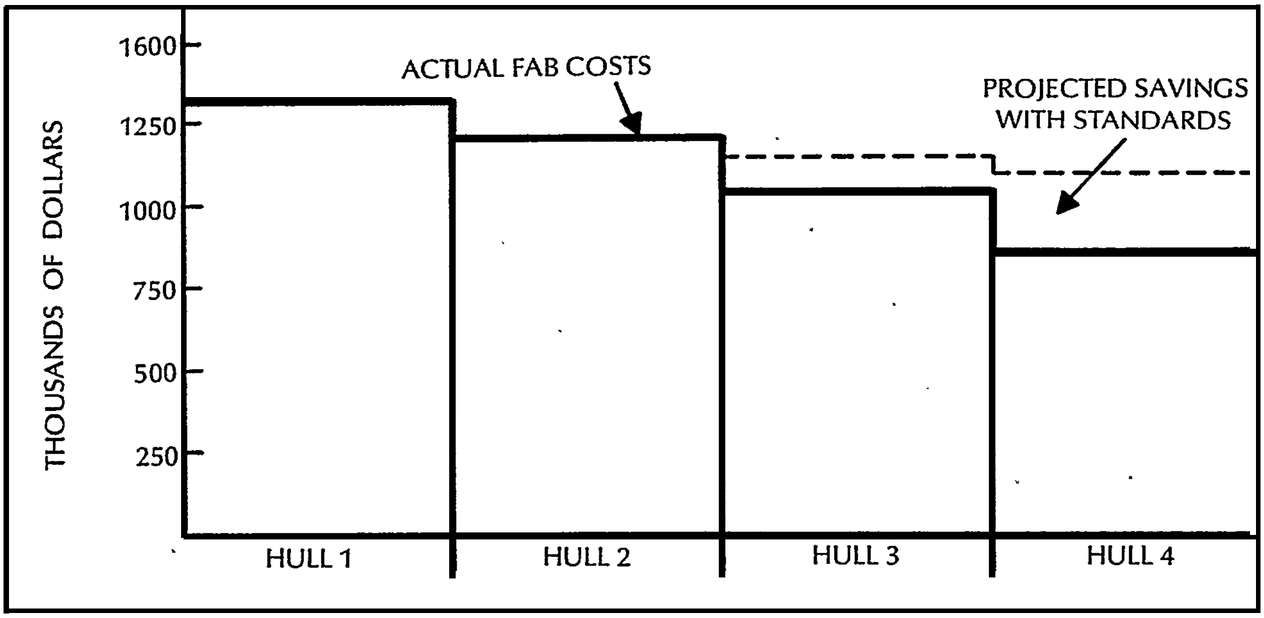


FIGURE 6: **SAVINGS FROM USE OF ENGINEERED STANDARDS**
(Steel Fab Operations)

Cost-Benefit Analysis

The cost to develop and document the Engineered Standards for layout, burning, fitting and welding for steel fabrication operations was $30,000 (4,800 man-hours). This first cost element would be a one-time cost for a shipyard since it depends only on the plant layout, the machines and other facilities in use there, and the types of materials processed. As long as these factors are unchanged, the standards remain applicable.

The second cost element is the increased planning activity needed to apply the Engineered Standards toward development of work package standard budgets and time allowances. This would be a one-time cost per contract since work packages for a lead ship are typically applied (with perhaps some minor modification) to follow ships. Marginal increases in cost for applying standards to work packages in the experiment was $22,000 (3,300 man-hours).

The third cost element is the cost of collecting labor expenditure and progress data for use in measuring actual performance against the schedule and budget. This cost would be approximately 1% of fabrication costs which in the experiment was about $11,000.

The experiment was begun after steel fabrication operations had been started on the third hull and concluded after a representative sample of data had been collected on the fourth hull. Line 5 in Table 1 is the actual cost of all fabrication operations on all four hulls. Line 6 is the projected fabrication cost, based on results of the sample data collected on the last two hulls assuming standards were used throughout. Line 7 is the projected total cost of fabrication operations including the cost of standards. A comparison of actual cost of fabrication operations without standards (Line 5) and total cost with standards (Line 7) shows projected savings of $87 thousand and $269 thousand respectively.

COST ELEMENT	HULL 1	HULL 2	HULL 3	HULL 4
1. Standards Development	—	—	$ 30	—
2. Standards Application	—	—	22	—
3. Performance Data Collection	—	—	11	$ 11
4. Cost of Standards	—	—	$ 63	$ 11
5. Fab Costs W/O Standards	$1,300	$1,210	$1,160	$1,120
6. Projected Fab Costs W/Stds.	1,300	1,210	1,010	840
7. Projected Cost W/Stds. (including cost of standards)	1,300	1,210	1,073	851
PROJECTED NET SAVINGS	- o -	- o -	$ 87	$ 269

TABLE 1: CALCULATED PAYBACK FROM USE OF ENGINEERED STANDARDS IN STEEL FABRICATION OPERATIONS
(Dollars in Thousands)

4. CONCLUSIONS - PAYBACK FROM THE RESEARCH

On the basis of the experimental results achieved it is concluded that:

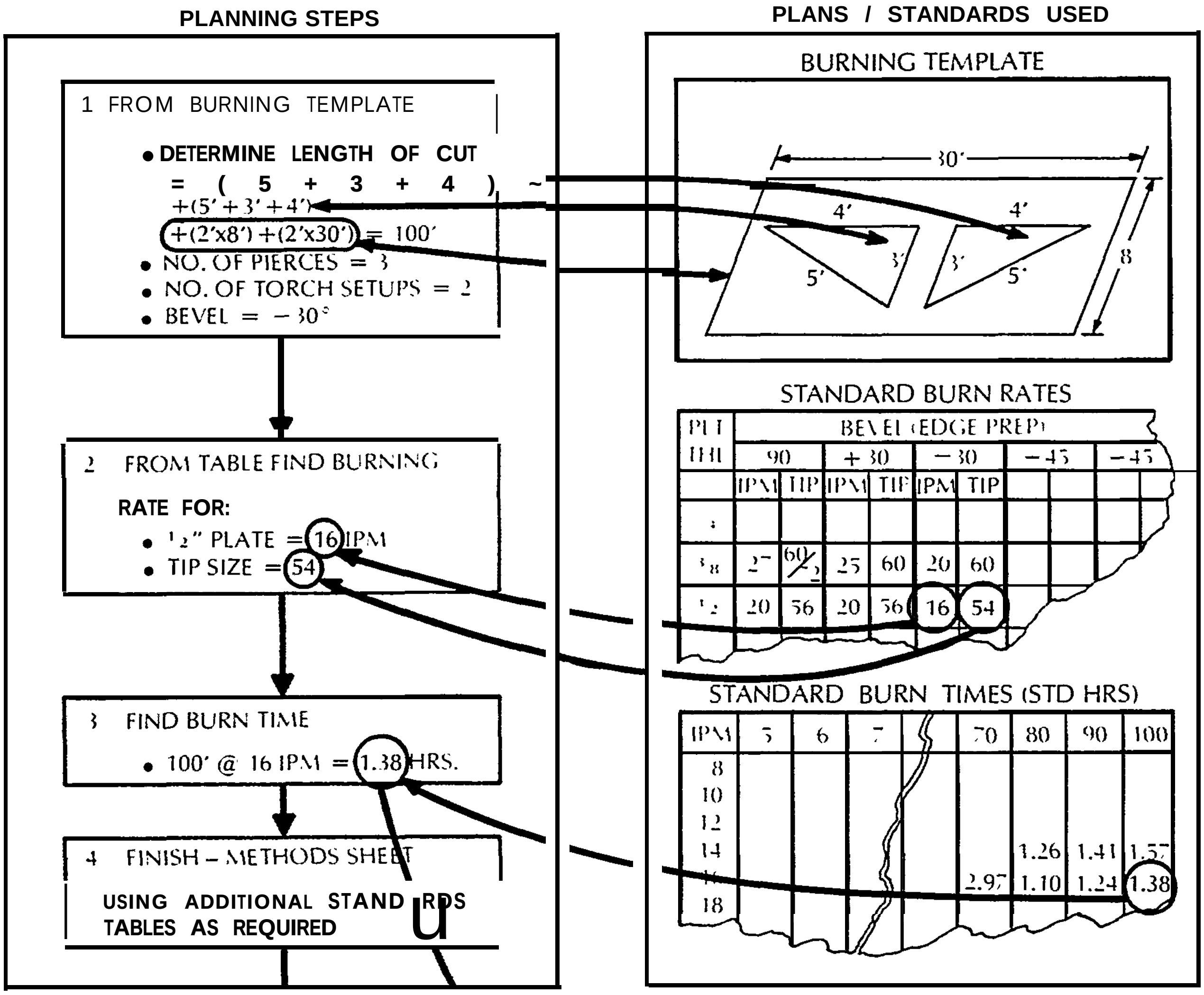
- The use of Engineered Standards in shipyard planning and production control will significantly improve schedule compliance and will increase shipyard productivity. Indeed, the contributions to cost reduction measured by the research far exceeded the rather conservative projections made early in the project.
- Costs of developing and applying Engineered Standards can be fully recovered on a single ship construction project and still yield net savings in fabrication costs.
- Shop labor will cooperate fully with the use of Engineered Standards in planning and production control if proper groundwork is laid.
- A fully informed and supportive shipyard management is essential to effective use of Engineered Standards.

5. RECOMMENDATIONS - THE NEXT STEPS

- Research in the use of Engineered Standards should be extended beyond steel fabrication to panel, assembly, erection and outfit operations.
- Value of Engineered Standards in higher level management functions such as bid estimating should be analyzed.
- Use of computer-aids to assist planners in the maintenance and application of Engineered Standards should be evaluated.
- An introduction and promotional program on use of Engineered Standards should be prepared and presented to top level shipyard management throughout the industry.
- A Planning and Production Control Handbook tailored to shipyard use should be prepared.

SAMPLE USE OF STANDARDS
(TELEREX BURNING MACHINE)

The following excerpts show how a planner would use the standards to determine the hours prescribed to burn a specific plate. More detailed information is available in the Technical Report on this research program.



STANDARD HOURS WORK SHEET

OPERATION	BASE TIMES	NO. OCC.	TOTAL TIME
TEMPLATE SET-UP	0.352	1	0.352
TORCH SET-UP	0.032	2	0.064
PIERCE	0.020	3	0.060
BURN	1.380	1	1.380
TOTAL STANDARD HOURS			1.856

SHIP PRODUCIBILITY RESEARCH PROGRAM PUBLICATIONS

IMPROVED PLANNING AND PRODUCTION CONTROL (TASK O-2)

- Final Reports
- Executive Summary
- Literature Search
- Burning Rate Tables
- Welding Current Tables
  Weld Cost vs Fit Gap Tables
- Production and Scheduling Standards
  - Burning
  - Layout
  - Fitting (Fabrication Area Only)
  - Welding (Fabrication Area Only)

FEASIBILITY OF SHIPBUILDING STANDARDS (TASK S-15)

- Report of Castine Conference
- Executive Summary

ADVANCED PIPE TECHNOLOGY (TASK S-4)

- Final Report
- Executive Summary

IMPROVED DESIGN PROCESS (TASK D-2)

- Final Report
- Executive Summary

FEASIBILITY OF PROPULSION PLANT STANDARDS (TASK S-1)

- Final Report
- Executive Summary

SIMPLIFIED HULL FORMS & SERIES PRODUCTION (TASKS P-I/O-I)

- Final Report
- Executive Summary